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HARDY

THE HARDY-WEINBERG PRINCIPLE

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HUNTINGTON TWO COMPUTER PROJECT

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supported by the National Science Foundation, Grant GW-5883.

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HARDY

TEACHER MANUAL

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TEACHER MANUAL

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HARDY

TEACHER MANUAL

I. BASIC INFORMATION ABOUT THE UNIT

Subject Area: Biology

Topic: Hardy-Weinberg Principle (Population Genetics)

Grade Level: 10th - 12th

Computer Language: BASIC

Special Language

Feature: TAB

Abstract: The *HARDY* program leads a student through the formulation of the Hardy-Weinberg Principle and assists a student in determining the proportion of individuals (or organisms) within a population that are homozygous dominant, heterozygous dominant or homozygous recessive with regard to a certain trait. The student can either survey a population of his own to obtain data for the number of the population showing the dominant or the recessive trait, or he can work with a population of rats generated by the computer.

The *HARDY* package can be used not only to teach the Hardy-Weinberg Principle and its applications, but as a simple, self-contained unit on elementary probability. *HARDY* can also be used to focus a discussion on sampling techniques.

II. A SAMPLE RUN

POPULATION GENETICS STUDY - THE HARDY-WEINBERG PRINCIPLE

HAVE YOU TRIED THIS PROGRAM BEFORE (1=YES, 0=NO) ?0

THE HARDY-WEINBERG PRINCIPLE PROVIDES A SIMPLE WAY TO CALCULATE THE PROPORTION OF ORGANISMS IN A POPULATION THAT ARE HOMOZYGOUS DOMINANT, HETEROZYGOUS DOMINANT, OR HOMOZYGOUS RECESSIVE WITH REGARD TO A SPECIFIC TRAIT. ALL WE NEED TO DETERMINE THESE PROPORTIONS ARE THE PROPORTION ALLELES IN THE GENE POOL WHICH ARE DOMINANT FOR THIS TRAIT (P) AND THE PROPORTION WHICH ARE RECESSIVE (Q).

WE WILL GIVE YOU A POPULATION OF RATS TO WORK WITH. SOME HAVE SHORT HAIR, SOME HAVE LONG HAIR. SHORT HAIR IS DOMINANT, LONG HAIR RECESSIVE. THERE ARE 1000 SPECIMENS. HOW MANY RATS DO YOU WANT TO SAMPLE ?200

TOTAL NUMBER RECESSIVE = 46

TOTAL NUMBER DOMINANT = 154

WHAT PROPORTION OF THOSE EXAMINED SHOWED THE RECESSIVE TRAIT THIS IS Q^2 ?.23

TO DETERMINE THE VALUE OF P AND Q AND THE GENOTYPIC RATIOS, RECALL THAT:

1. $P + Q = 1$ SINCE THE PROPORTION OF ALLELES IN THE GENE POOL WHICH ARE DOMINANT FOR A TRAIT PLUS THE PROPORTION WHICH ARE RECESSIVE REPRESENT ALL ALLELES IN THE GENE POOL,
 2. P^2 REPRESENTS THE PROPORTION OF THE POPULATION THAT ARE HOMOZYGOUS DOMINANT,
 3. $2PQ$ REPRESENTS THE PROPORTION THAT ARE HETEROZYGOUS DOMINANT,
 4. Q^2 REPRESENTS THE PROPORTION OF THE POPULATION THAT SHOW THE RECESSIVE TRAIT, I.E. THAT ARE HOMOZYGOUS RECESSIVE,
 5. $P^2 + 2PQ + Q^2 = 1$ SINCE THE PROPORTION OF THE POPULATION THAT ARE HOMOZYGOUS DOMINANT, PLUS THE PROPORTION THAT ARE HETEROZYGOUS, PLUS THE PROPORTION THAT ARE HOMOZYGOUS RECESSIVE REPRESENT THE TOTAL POPULATION.
-

IN THE ABOVE EXAMPLE, $Q = 0.479583$

GENOTYPE	PROPORTION	NUMBER
HOMOZYGOUS DOMINANT	0.27	54
HETEROZYGOUS DOMINANT	0.5	100
HOMOZYGOUS RECESSIVE	0.23	46

DO YOU WISH TO REPEAT THIS PROGRAM (1=YES, 0=NO) ?1

DO YOU WISH TO COMPILE YOUR OWN INFORMATION ON A SPECIFIC TRAIT (1=YES, 0=NO) ?1

NUMBER OF ORGANISMS EXAMINED ?1000

NUMBER OF ORGANISMS SHOWING RECESSIVE TRAIT ?150

WHAT PROPORTION OF THOSE EXAMINED SHOWED THE RECESSIVE TRAIT THIS IS $Q \times Q$?.15

$Q = 0.387298$

GENOTYPE	PROPORTION	NUMBER
HOMOZYGOUS DOMINANT	0.38	375
HETEROZYGOUS DOMINANT	0.47	475
HOMOZYGOUS RECESSIVE	0.15	150

III. INSTRUCTIONS FOR RUNNING HARDY

The first time the student uses the program, he receives a brief explanation of the Hardy-Weinberg Principle and a sample rat population to work with. When the student has specified the number of rats he wants to sample, the computer will generate the number of rats showing the dominant trait (short hair) and the number showing the recessive trait (long hair). Following this information the computer will calculate and print out Q^2 , the proportion of rats in the sample showing the recessive trait; Q , the frequency of the recessive allele in the sample population; and the proportion and the number of rats that are homozygous dominant, heterozygous dominant or homozygous recessive with respect to the trait in question.

On subsequent runs of the program, the student has the option of either using his own data or working with either of two rat populations generated by the machine. (The "original" rat population is set at 19% recessives*; the percentage of recessives in the "new" rat population varies randomly.) In each case, the computer will calculate and print out Q^2 and Q for the sample population and the genotypic ratios for that population.

IV. USING HARDY IN THE CLASSROOM

Before Using HARDY

In the STUDENT MANUAL, there are instructions for running the HARDY program, a brief section on how to construct a sample, and a list of procedures for conducting a survey to gather data for the frequency of occurrence of a certain trait within a population. In addition to this information, students should be familiar with certain basic concepts and terms from genetics: e.g., the concept of a gene pool, allele frequency, equilibrium population, natural selection, and the meaning of the terms homozygous dominant, heterozygous dominant, and homozygous recessive.

In the RESOURCE MANUAL, you will find a section on the formulation of the Hardy-Weinberg Principle. This formulation was written with the student in mind and is presented, even though it entails the introduction of a small (very small) amount of probability theory, because we feel that the Hardy-Weinberg Principle can be learned and used with ease only when its meaning is fully understood.

*Because sampling is done with replacement, the actual % of recessives may vary slightly from trial to trial.

Classroom Procedure

Probably the most effective way of using the program is with "real" data, but this requires student participation in gathering the necessary information. Fortunately, there are several human traits which are single-gene, dominant-recessive characteristics. These include the following:

- Taster vs. nontaster for PTC (Phenylthiocarbamide)
- Free ear lobe vs. attached ear lobe
- Tongue roller vs. non-tongue roller

The STUDENT MANUAL contains instructions for surveying a sample population with regard to any or all of these traits. (You might have your students come up with the actual plan for surveying the area or neighborhood to be covered.) When your students return with the sample data, they can pool their data by placing totals for each trait on the board.

At this point you can have each group (maximum: 5 people/group) run the program for one set of data, e.g., data for free-attached ear lobes, at a time. If possible, let your students try to calculate the genotypic ratios before running the program; they can then check their calculations on the machine.

An Alternative Use of the Program

HARDY can also be used without "real-life" data. If necessary, students can work with either one or both of the rat populations generated by the computer; as was mentioned earlier, the "original" rat population, which the student gets the very first time he runs *HARDY*, has a fixed proportion of recessives (.19), while the proportion of recessives in the "new" rat population varies from population to population. In using the program with stored data, you might use the same technique of dividing your class into small groups. When each group has completed several runs of the program, you might have them work out problems similar to the ones given below. When they have finished, they can check their solutions at the computer.

PROBLEM 1: Assume that the gene for white wool in sheep is dominant over the gene for black wool. If 250 out of 1000 sheep observed in a large population have black wool, what per cent are homozygous white and what per cent are heterozygous white?

Solution to PROBLEM 1

Given: 250 out of 1000 sheep show the recessive trait

Then: $Q^2 = 0.25$ (Note: $P^2 \neq 0.75$)

And: $Q = 0.5$

Since: $P + Q = 1$ or $P + 0.5 = 1$

Then: $P = 0.5$

Thus: $P^2 = 0.25$ (25%)

Thus: $2PQ = 2(0.5 \times 0.5) = 0.50$ (50%)

Answer: Homozygous White Wool = 25%
Heterozygous White Wool = 50%
Homozygous Black Wool = 25%

PROBLEM 2: If we know that 128 out of 200 people surveyed for being tasters or nontasters of PTC show the dominant characteristic, what per cent of the general population (approximately 1000 people) are heterozygous?

Solution to PROBLEM 2

Given: 72 out of 200 people show the recessive characteristic

Then: $Q^2 = 0.36$ (Note: $P^2 \neq 0.64$)

And: $Q = 0.6$

Since: $P + Q = 1$ or $P + 0.6 = 1$

Then: $P = 0.4$

Thus: $P^2 = 0.16$ (16%)

Thus: $2PQ = 2(0.4 \times 0.6) = 0.48$ (48%)

Answer: Homozygous Dominant Tasters = 16%
Heterozygous Dominant Tasters = 48%
Homozygous Recessive Nontasters = 36%

PROBLEM 3: Polydactilism in humans is the condition of being six-fingered. Although this condition is dominant over the five-fingered condition, 97% of the general population are five-fingered. What per cent of the population are homozygous dominant and what per cent are heterozygous?

Solution to PROBLEM 3:

Given: $Q^2 = 0.97$ (Note: $P^2 \neq 0.03$)

Then: $Q = 0.985$

Since: $P + Q = 1$ or $P + 0.985 = 1$

Then: $P = 0.015$

Thus: $P^2 = 0.000225 \cong 0.0$

Thus: $2PQ = 2(0.015 \times 0.985) = 0.029550 \cong 0.03$

Answer: Homozygous Dominant Six-Fingered = 0% (Rounded off)
Heterozygous Dominant Six-Fingered = 3% (Rounded off)
Homozygous Recessive Five-Fingered = 97%

When you have completed all phases of this program, it might be worthwhile to have some students pose problems similar to those given above, while other students solve the problems. This approach may resolve any remaining difficulties that students might have with the Hardy-Weinberg Principle.

V. FOLLOW-UP QUESTIONS AND ANSWERS

These questions may be used to stimulate a discussion or as a written assignment.

- 1) a. What is meant by a sample of a population?
 b. What is meant by a population?
- 2) Why should the sample be random? (Not selective?)
- 3) What constitutes a good sample? a bad sample?
- 4) Sampling error refers to all the mistakes that an investigator might make by using a nonrepresentative sample. It's measured as a difference between the estimate produced by sampling and the actual figures existing in the entire population. How might sampling errors occur?
- 5) How might sampling errors affect the outcome?
- 6) Under what conditions can the Hardy-Weinberg Principle be applied?
- 7) Suppose mating were not random. How would this affect the population of the next generation in terms of a shift in gene concentrations?
- 8) Suppose immigration occurs. How would this affect the population of the next generation? What about emigration?
- 9) Why is it advantageous for a species to have very large numbers (10,000 members or more) of breeding individuals?
- 10) What is genetic drift?
- 11) Why is it difficult to apply the Hardy-Weinberg Principle in real life?
- 12) Why is completely random mating rare?
- 13) Why do predictions for the genetic make-up of a population differ from Darwin's theory of natural selection and the Hardy-Weinberg Principle?

Sample Answers to Questions

- 1) A sample of a population is a selected portion of the total population. For our purpose, the population consists of the total number of individuals of a single species found within a defined area.
- 2) If a random sample is not taken, the frequency of a particular trait within the sample may differ substantially from the frequency of the trait within the general population.
- 3) A good sample will give you a close estimate of a condition that exists within an entire population. The better the sample, the better your estimate. The term "good" or "bad" is relative and will depend upon the need for accuracy, the statistical analysis used, and the method of sampling. Random sampling is best for determining the frequency of a specific genetic trait. In general, the larger the sample size, the more meaningful the results relative to the entire population.
- 4) There are several ways sampling errors can occur. These include:
 - a) two or more students using the same family;
 - b) a large family's statistics being used and these statistics weighting results in their genetic favor;
 - c) the sampler confusing the data.
- 5) If the proportion of recessive Q^2 in the sample population is not equal to the proportion of recessives in the total population, the allele frequencies P and Q and the genotypic ratios P^2 and $2PQ$ calculated from Q^2 will also be incorrect for the total population.
- 6)
 - a) The population must be large enough so that chance alone cannot significantly affect gene frequencies.
 - b) The amount of immigration or emigration is negligible.
 - c) There is essentially no mutation or there is mutational equilibrium.
 - d) Individuals of each genotype have equal chances of surviving and leaving offspring.
 - e) Mating is entirely random. (There is no selection for a particular trait.)

- 7) If mating were selective, the traits which were being selected for would have a greater gene concentration in the next generation. This would increase the proportion of those individuals showing those specific traits and decrease the proportion of those individuals not showing the traits.
- 8) If the immigrants have gene frequencies different from those of the general population for certain traits, then the greater the genetic differences the greater the effect on the gene pool of the general population. If there is emigration and the emigrants as a group have gene frequencies different from those of the general population for any trait, the gene pool of the population in question will also change.
- 9) Large numbers of breeding individuals of a particular species ensures that favorable genetic traits will not be lost. With a small number of members, the frequencies of genetic traits can shift drastically from one generation to the next, and in some cases superior traits can be lost.
- 10) When we look at one genetic trait in a large population over a series of generations, the frequency of that trait may change slightly by chance. This is referred to as genetic drift.
- 11) The Hardy-Weinberg Principle assumes that essentially no mutations occur or that mutational equilibrium exists. This never happens in a population; mutations are always occurring. Also, totally random mating seldom, if ever, occurs.
- 12) Individual matings occur as a result of numerous extrinsic factors. These include:
 - a) proximity (closeness to one another)
 - b) selection for desirable traits
 - c) aggressiveness of either sex
- 13) Natural selection prevents the implementation of random mating; therefore, the gene frequencies for selected traits will change from one generation to the next.



